CHAPTER 17

Computer Programs

CONTENTS

	Paragraphs
Introduction	1 - 3
Loading	4 - 7
Ultimate Strength	8 - 9
Detailed Structural Analysis	10 - 13
General Design and Optimisation	14 - 19
Composite Materials	20 - 21
Artificial Intelligence	22 - 23

CHAPTER 17

Computer Programs

Introduction

1 The purpose of this chapter is to provide a brief introduction to, and summary of, some available computer programs to support the analysis required by the foregoing chapters, and to provide some limited guidance to the reader on program suitability. Generally, programs providing analysis methods which are not called up in this book, or those not readily available in the UK, will not be discussed. Furthermore, each reader is likely to have access to some specialised or locally produced programs which are not on the open market and these again will obviously not be covered here. As a general rule, however, whatever program is to be used, it is essential that the user ensures that it is properly validated for the relevant design regime and that the documentation states clearly the assumptions made by the programmer and the limitations of the program. Only then can the user be sure that he is not operating the program outside the parameter limits intended by the writer.

2 It also should be emphasised that it is essential that all data input to a computer program should be rigorously checked, using a computer based checking routine if one is available. However, such routines are far from fully reliable and there is no substitute for a line by line check by the user. Similarly, when making use of the output the *whole* set should be studied, not only the subset which is actually required, so that any anomalies can be identified and the reasons discovered before use is made of the results.

3 The layout of this chapter will be roughly the same as the rest of the book, that is commencing with loading, then ultimate strength analysis, followed by local strength and finite element analysis. The structural aspects of computer aided design programs are then discussed together with programs which enable some form of structural optimisation. The chapter concludes with discussion of some other program types such as those calculating properties of composite materials, and the potential for use of artificial intelligence in structural design.

Loading

4 Reference to Chapter 3 will show that there are two principal techniques discussed for estimation of wave loading, which are strip theory and static balance. Strip theory itself may be divided into two approaches, that of rigid body analysis and that of modal analysis assuming the hull to be a flexible non-uniform beam. The rigid body approach is the most common and the majority of programs are based on SCORES reported by Raff (1972). In the implementation of

these programs there are small differences in the internal routines which make some programs more suitable for the prediction of ship motions while others are written with derivation of wave bending moments and shear forces specifically in view. Consequently, the user should be a little cautious in choice of program, see for example Clarke (1986). Note, however, that all these programs use a strictly linear analytical technique as described in Chapter 3 and run in the frequency domain so that no allowance is made for non-linear motions and the hull form is assumed wall sided. Consequently, extreme motions and loads are outside the range of validity of the programs in, in general, loads are *over*estimated.

5 The only modal analysis programs readily available are those due to Bishop, Price and Tam (1977) with the theory fully described by Bishop and Price (1979). The theory is embodied in a series of programs, the principal ones of which are UCLMARS, IRREGULAR and UCLSLAM. The first of these calculates the modal responses of a flexible non-uniform beam to a series of regular sinusoidal wave excitations, and the second uses linear superposition to provide the response to a statistically defined irregular sea (incidentally, IRREGULAR is also needed for calculation of actual loading responses to regular waves, because UCLMARS only outputs the response amplitude operators). UCLSLAM, as its name implies, estimates the frequency and severity of slam responses. These programs are still operating in the linear frequency domain and so the same limitations apply as for the rigid body programs. In fact, for the rigid body responses, these programs produce results that are indistinguishable from SCORES based programs, and for most design purposes it is only the rigid body responses that are of interest. However, for a discussion of the effects of hull flexibility on the results see Bishop (1989) and for a design procedure which allows for hull flexibility see Chalmers (1988(b)).

6 Static balance methods for estimating bending moments and shear forces are included in many naval architectural program suites. On the whole these are reliable and well validated, but it is always worth checking on the limits of wave height that are acceptable. In particular, the program should cater for wave profiles which drop below the line of keel or rise above the upper deck; the 8 m wave height recommended in Chapter 3 is large in relation to the depth of most hulls up to destroyer size and that artificial wave condition frequently exists. Another point to be checked in static balance programs is how they deal with the overhang beyond the fore and aft perpendiculars; the precise method is unimportant but it should be properly documented and consistent, and not constrain the natural form of data input in any way. A good check on the results from a static balance program is the accuracy of closure at the ends of the shear force and bending moment distributions. They should both, of course, be zero, but the numerical integration involved always causes one end to diverge slightly. If the divergence is large, or if both ends are exactly zero, then some suspicion should be aroused. Ideally, the method of adjusting the closure, if any, and the acceptable tolerance should be described in the documentation.

7 Programs are currently being developed which combine the non-linear geometrical advantages of static balance with the dynamic abilities of strip theory. These have to work in the time domain as there cannot be a closed form solution to the frequency equations; consequently, even though they are implemented on supercomputers, they can take a long time to run to achieve meaningful results as they involve solving the instantaneous equations of motion stepwise in both space and time for a full description of the response to a particular wave train. Nevertheless, as the work in this field progresses it is likely that such programs will improve very considerably the designer's ability to predict wave loading in extreme conditions.

8 Programs for calculating the ultimate strength of the hull girder as recommended by Chapter 7 are not very common and are generally specific to a particular organisation. This is partly because of the inevitable complexity of the procedure which makes it difficult for a reliable program to be released into the public domain, and partly because there is not currently a large demand for the method. However, the programs are all based on some form of 'load shortening curve' calculation as described by Smith (1977) and generalised by Smith et al (1988), carried out for each different plate-stiffener combination around the girth. From the integrated properties of each plate-stiffener combination a bending moment-curvature plot for the complete hull section is then developed as described in paragraph 71 of Chapter 7 and illustrated in *Figure 7.10*. This plot is then used to derive the ultimate strength of the hull girder.

9 Within the UK Ministry of Defence the programs that carry out these calculations are first FABSTRAN, described by Dow and Smith (1986) for production of the load shortening, and secondly NS94 described by Smith and Dow (1986) to find the ultimate strength. Both these programs require considerable care to operate, especially FABSTRAN which is a very wide ranging and flexible program capable of doing far more than is required in this context. It can, for example, investigate transient non-linear responses, and undertake ring frame analysis. Consequently, before use of the programs is attempted a thorough study of the references, which comprise user manuals, is essential and even then advice will probably be needed from the authors until sufficient experience is gained.

Detailed Structural Analysis

10 For carrying out analysis of local structure, such as grillages, under various load conditions there used to be a variety of stand alone programs available. However, with the advent of simple and readily usable pre- and post-processors for general finite element analysis programs (described below) the specific programs have mostly gone out of use, principally because they each required preparation of data in a different format. One particular program, GRILL discussed by Clarke (1977) and the basis of the overall grillage buckling procedure described in Chapter 7 and by Clarke (1979), is worth mentioning because it uses the orthotropic plate method (see Chapter 10) for estimation of both deflections and stresses under lateral and in-plane loads on grillages. This is a valuable program and is quicker to use than a finite element method where calculation of critical buckling stresses is the aim and the data sheets in Chapter 18 are inadequate for the accuracy required. Additionally, this program is built into the MOD Computer Aided Design suite GODDESS (see paragraph 14) as part of the bulkhead analysis package.

11 For detailed analysis of structure the most powerful methods now available are the family of finite element and finite difference techniques. These can only be used as computer programs because of the enormous number of mathematical operations required in solving, frequently, thousands of equations, although the theory is not complicated, see for example Zienkiewicz, 'The Finite Element Method'. Computer programs vary from the limited special application type of which there are many, usually with rather samll element libraries, through the main general purpose programs such as NASTRAN, SESAM and PAFEC to very complex non-linear

programs such as ASAS NL developed for the Defence Research Agency, Dunfermline for dealing with shock, blast and impact analysis. A description and review of the many finite element analysis programs available internationally for ship structural analysis, together with a full set of references, is presented in the report of the International Ship and Offshore Structures Congress (ISSC) Committee V.5, 'Design Optimisation' (1988). A similar coverage of non-linear finite element codes used for buckling, ultimate strength and vibration analysis is given in the ISSC report of Committee III.1, 'Ductile Collapse' (1988). A review of finite element codes suitable for use on microcomputers is given by MacKerle (1987).

12 It is the main general purpose programs that the structural designer is most likely to use, and in particular NASTRAN and PAFEC seem to be currently the most popular with the UK warship design fraternity. Because of their general capabilities the preparation of data and interpretation of the output are tedious for any realistic size of problem, and for a long time this aspect deterred many potential users. However, there are now available a variety of pre- and post-processors, for example PATRAN, SUPERTAB and the FEMGEN/FEMVIEW family, which greatly simplify the input and output of data by using the graphical capabilities of modern computers. Indeed, much of the more recent development effort has gone into graphical displays which in many cases can imply to the designer that the results are more accurate than they really are! It must never be forgotten that finite element methods are, at best, a crude compromise and can never give a completely accurate answer. This is because the problem has to be discretised, and because assumptions must be made concerning the strain or deflection distribution across elements so that they fit the mathematical requirements for a closed form solution. In consequence, the true physical state is far from fully represented and it is essential that these methods are used with care and for each problem the level of accuracy of the result should be assessed. For further details of the use of finite element analysis see the NAFEMS publications 'Guidelines to Finite Element Practice' and 'A Finite Element Primer'.

13 The majority of structural problems requiring solution can be covered by using simple plate and beam elements allowing for bending and shear effects, and such elements are available in all the common programs. For a combination of plates and stiffeners care should be taken to ensure that a good estimate of effective breadth of plate is added to the stiffener bending properties, because unless the finite model is very refined and designed specifically to achieve it, shear lag effects are not accounted for. Occasionally, if there is a need to investigate through the thickness responses in, say, a hatch coaming, then use of solid or 'brick' elements will be necessary. As soon as such three dimensional aspects are included in a model there is a manifold increase in complexity and accurate results are even more difficult to achieve; specialist advice should be sought before attempting such an analysis. At its most complex, finite element analysis can be used to solve both buckling and vibration problems and problems involving non-linear and impact loading, but these should not be attempted by any but the most experienced user; generally, in such cases it will be better to contract out such problems to specialists when they cannot be solved by more direct analytical methods.

General Design and Optimisation

14 There are four programs generally accessible which cover all or part of the overall design of ships and which include a greater or lesser structural element. The most general is the UK

GODDESS suite of programs, described in the 'GODDESS User Manual' (1986), which is a computer aided design package aimed mainly at establishing the geometry, layout and weight balance of a warship using a very sophisticated and flexible database to ensure consistency within a particular design. It does not have any structural *design* capability, but structural scantlings can be input as data at a hull cross section and the program contains an analysis capability to estimate the stresses and margins against failure under a given bending moment and shear force, for each of the 'panels' of the section. The analysis algorithms only allow for simple linear buckling and yield failure and so should only be used as a first estimate of the acceptability of the structure when using GODDESS in association with the design procedures of Chapters 6 and 7.

15 The second program in this series is RASDAS marketed by BMT CORTEC Ltd and described in the RASDAS Users Manual (1987). This is a program intended for structural design and indeed will synthesise a section given the overall geometry and the primary and secondary loading. However, it currently has a number of limitations which make it not entirely suitable for warships, for example only longitudinal structure of flat panels stiffened in the longitudinal direction can be created and analyzed, and only one design wave loading can be applied at once (in other words the worst envelope of the hogging and sagging effects cannot be derived). Although supported by BMT the program requires a significant number of enhancements which may be added in due course.

16 A similar but much more developed program is the US Navy DPSS program, use of which is described by Devine (1988). This again creates the structure from a given set of loads and the hull geometry, but allows for combined loads and curvature of the structure. It can also accommodate less conventional geometries such as asymmetric arrangements (aircraft carriers) or SWATH vessels. However, DPSS contains only the US Navy's standard material and section data as well as their design failure criteria, which differ significantly from the UK approach described in this book. Consequently, DPSS should be used with care to produce a first approximation to the structure which must then be updated by other means to the relevant standards.

17 The final program in this series is MAESTRO, the theory of which is described by Hughes (1983). This is a coarse finite element program which generates its own elements based on the plate arrangement and stiffener spacing. Its most valuable capability is the fact that it can optimise a structural arrangement for minimum weight given a geometry and starting point, and a set of loading conditions. It cannot *create* a structure, but can accept a relatively unrepresentative input, for example that created by DPSS. There are a number of versions of MAESTRO in existence, each with a particular organisation's material and section properties and failure criteria built into the software, so it is important to be sure that the correct version is being used.

18 The most promising line of use for these programs is to use GODDESS to create the hull geometry, to input that geometry to DPSS to create a first approximation to the structure and then to use MAESTRO to refine that structure to the appropriate standards. MAESTRO, being a finite element program, can then define the boundary conditions for detailed finite element analysis so that, for example, fatigue calculations can be undertaken in local areas of the structure. Unfortunately, however, none of these programs is interfaced to any other so at each stage it is necessary to take the output and to analyse it and reduce it 'by hand' to create the input files for the next program. This is not necessarily a bad thing as it forces the designer to be aware at each stage of the details of the development of the design and to make changes if it appears to be diverging from what is expected, but it clearly does not take full advantage of the potential computing power available, and also allows more opportunity for designer generated mistakes.

19 Whilst in this area it is worth mentioning some programs which do not fit the normal design processes but which may be required in particular cases, that is for the establishment of vulnerability of the structure to weapon effects. The first is SUBWHIP which calculates the whipping contours under a ship as described in Chapter 15 by Hicks (1986), and the others are SSVUL, REVS and DEVS described by Greenhorn (1988) which assess the probability of various types of damage, SSVUL to underwater attack and the other two to above water attack. All these programs require rather specialised understanding to use reliably and advice should be sought from specialists before any initial attempt.

Composite Materials

20 The analysis programs described previously in general assume that the materials are isotropic, which for practical purposes means that they are metals, but usually any number of different isotropic materials can be combined in the input data set provided care is taken in interpretation of the output when relating stress and strain. However, with the increasing use of composite materials it is desirable to be able to input orthotropic and anisotropic material properties. Most of the general purpose finite element programs allow the input of laminar materials, where each laminate has different orthotropic properties, so that route can be followed if sufficient data on the laminate is available. Similarly, these programs allow the user to input a generalised material property matrix which therefore can be totally anisotropic. Most of the other analytical programs mentioned above, however, do not have either of these capabilities.

21 In any case, estimating properties for non-isotropic materials is tedious and a number of computer programs exists to reduce the effort. A typical one is LAMANAL, originally produced by Cranfield Institute of Technology and now marketed by Analysis and Design Consultants Ltd of Newport Pagnell, which enables the user to calculate the stiffness matrix or any particular property of any composite laminate provided the properties of the individual components are known. In many cases, at least if the reinforcement consists of random mat or a balanced weave of fibres, it will then be sufficient to take the in-plane tensile properties in one of the principal directions and use those as if the material was isotropic.

Artificial Intelligence

22 Developments are now in hand to investigate the potential for the use of artificial intelligence in structural design. It is possible that programs known as 'Expert Systems' could be used to guide the designer through the complexities of, for example, the procedures of Chapters 6 and 7, asking appropriate questions and perhaps looking up digitised forms of the data sheets.

Alternatively, such a system might run alongside other computer programs as a built-in 'help' system, questioning the user if he strays from the expected path, or protecting him from misuse of the program. A third possibility is a form of expert or intelligent pre-processor for assistance in preparation of data for, say, a finite element program, to relieve the user of the need to read much of the documentation which may not be relevant to his problem.

23 Artificial intelligence is still, however, in its infancy, and although there are many small systems presented in the literature their applicability is strictly limited. Larger successful systems only exist in other disciplines, for example in medical diagnosis, and the theoretical approaches to these programs are not appropriate to engineering design. Nevertheless, with the number of experienced structural designers declining rapidly because of the reducing number of new ships, the need for some means of retaining expertise in some manner, which may involve computer techniques, is gaining in importance and in urgency, although computers can never totally replace human specialists.